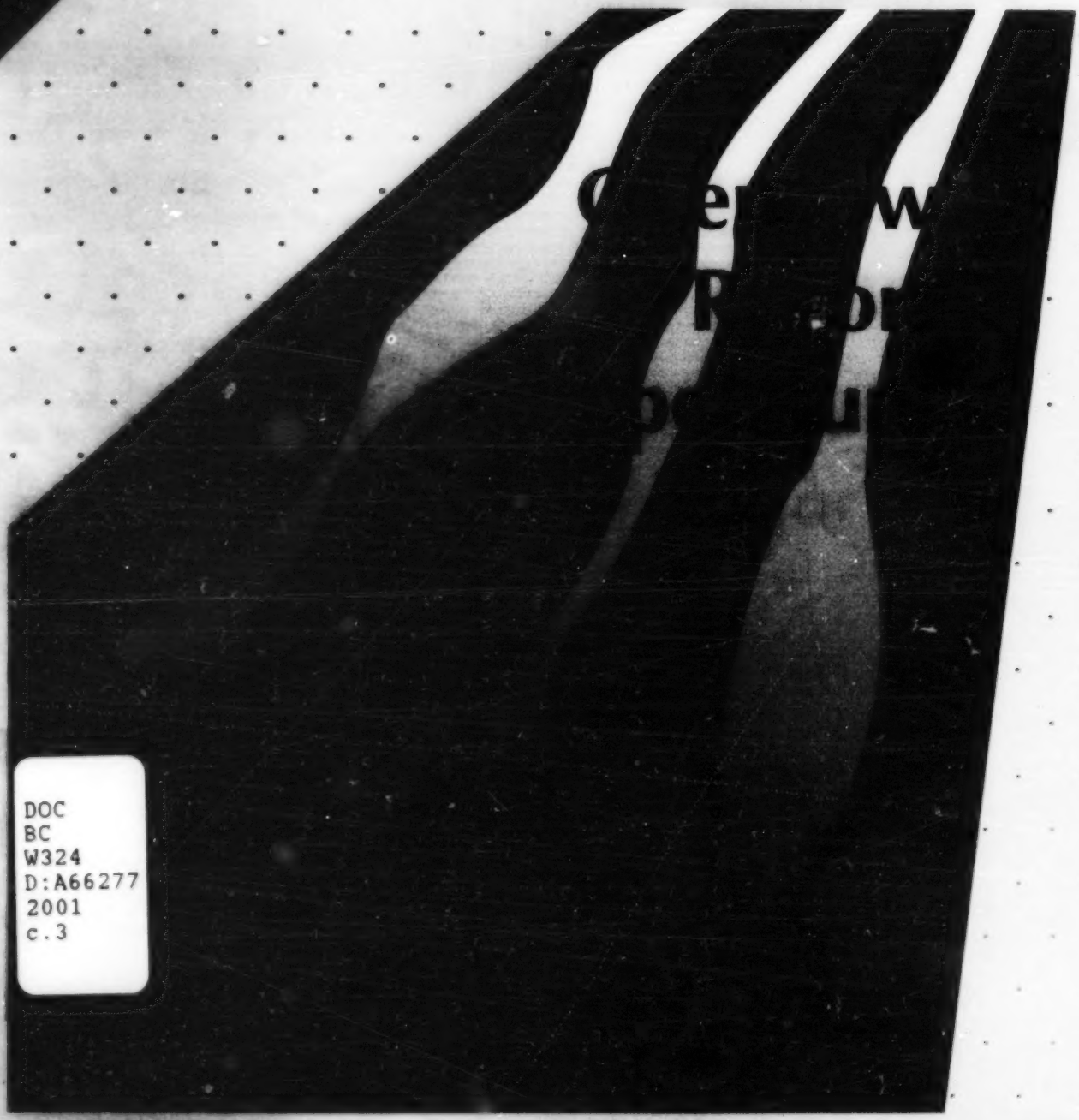
Ministry of Water, Land and Air Protection

OVERVIEW — TEMPERATURE

Water Quality GUIDELINES



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MINISTRY OF WATER, LAND AND AIR PROTECTION

AMBIENT WATER QUALITY GUIDELINES FOR TEMPERATURE

OVERVIEW

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SUMMARY

THIS DOCUMENT is one in a series which establishes ambient water quality guidelines for British Columbia. It is based a report prepared by G.G. Oliver and L.E. Fidler of Aspen Applied Sciences Ltd. under contract to the former BC Ministry of Environment, Lands and Parks. The Consultant's report, *Towards a Water Quality Guideline for Temperature in the Province of British Columbia*, provides the scientific background information, recommends guidelines and provides the supporting documentation.

The guidelines are safe conditions or levels of a variable which have province-wide application and are set to protect various water uses. This report sets guidelines for temperature, as appropriate, to protect drinking water, freshwater and marine aquatic life, wildlife, recreation and aesthetics, irrigation, livestock watering, and industrial water uses. The guidelines recommended by the consultants were adopted by the province, except where certain adjustments were deemed necessary as follows:

- For recreation and aesthetics, the guidelines recommended by the consultants were replaced by the Guidelines for Canadian Recreational Water Quality, which are used by the British Columbia Ministry of Health Services. Guidelines relating to public health at bathing beaches fall under the authority of the British Columbia Ministry of Health Services.

The guidelines are summarized in Tables 1 and 2 on the following pages.

A major use of the guidelines is to set ambient water quality objectives. The objectives are the guidelines modified or adopted to protect the most sensitive designated water use in a particular body of water. The objectives are used in the preparation of waste management plans, pollution prevention plans, waste management permits, orders, or approvals. These waste management permits, orders and approvals are the only documents that have legal standing.

TABLE 1: SUMMARY OF WATER QUALITY GUIDELINES FOR TEMPERATURE

Water Use	Recommended Guideline
Drinking Water	15°C Maximum
Recreation and Aesthetics	30°C Maximum Narrative[1]
Aquatic Life ***Freshwater***	
Streams with Unknown Fish Distribution	MWMT[2] = 18°C (Max Daily Temperature = 19° C) Hourly rate of change=1°C Maximum Incubation Temperatures (Spring & Fall) = 12° C
Streams with Known Fish Distribution	± 1° C beyond optimum temperature range (as per Table 2) for each life history phase of the most sensitive salmonid species present. Hourly rate of change =1°C
Streams with bull trout and/or Dolly Varden	Maximum Daily Temperature = 15° C Maximum Incubation Temperature = 10° C Minimum Incubation Temperature = 2° C Maximum Spawning Temperature = 10° C
Lakes and impoundments	Change from natural ambient background = ±1°C
Marine, estuarine	Change from natural ambient background = ±1°C Hourly rate of change = 0.5°C Narrative[3]
Wildlife, livestock watering, irrigation and industrial water supplies	Change from natural ambient background = ±1°C

[1] The thermal characteristics of waters used for bathing and swimming should not cause an appreciable increase or decrease in the deep body temperature of bathers and swimmers.

[2] MWMT = Mean Weekly Maximum Temperature is defined as the average of the warmest daily maximum temperatures for seven consecutive days.

[3] The natural temperature cycle characteristic of the site should not be altered in amplitude or frequency by human activities.

TABLE 2: Optimum Temperature Ranges of Specific Life History Stages of Salmonids and Other Coldwater Species for Guideline Application.

Species	Incubation	Rearing	Migration	Spawning
Salmon				
Chinook	5.0-14.0	10.0-15.5	3.3-19.0	5.6-13.9
Chum	4.0-13.0	12.0-14.0	8.3-15.6	7.2-12.8
Coho	4.0-13.0	9.0-16.0	7.2-15.6	4.4-12.8
Pink	4.0-13.0	9.3-15.5	7.2-15.6	7.2-12.8
Sockeye	4.0-13.0	10.0-15.0	7.2-15.6	10.6-12.8
Trout				
Brown	1.0-10.0	6.0-17.6		7.2-12.8
Cutthroat	9.0-12.0	7.0-16.0		9.0-12.0
Rainbow	10.0-12.0	16.0-18.0		10.0-15.5
Char				
Arctic char	1.5-5.0	5.0-16.0		4.0
Brook trout	1.5-9.0	12.0-18.0		7.1-12.8
Bull trout	2.0-6.0	6.0-14.0		5.0-9.0
Dolly Varden		8.0-16.0		
Lake trout	5.0	6.0-17.0		10.0
Grayling				
Arctic grayling	7.0-11.0	10.0-12.0		4.0-9.0
Whitefish				
Lake whitefish	4.0-6.0	12.0-16.0		>8.0
Mountain whitefish	<6.0	9.0-12.0		<6.0
Other species				
Burbot	4.0-7.0	15.6-18.3		0.6-1.7
White sturgeon	14.0-17.0			14.0

PREFACE

THE MINISTRY OF WATER, LAND AND AIR PROTECTION develops ambient water quality guidelines for British Columbia. This work has two goals:

- to provide guidance for the evaluation of data on water, sediment and biota, and
- to provide basis for setting site-specific ambient water quality objectives;

The guidelines represent safe conditions or safe levels of a substance in water. The term "guideline" is defined as "a maximum and/or a minimum value for a physical, chemical or biological characteristic of water, sediment or biota, which should not be exceeded to prevent detrimental effects from occurring to a water use under given environmental conditions."

Water Quality guidelines are applied province-wide, but they are use-specific, and are being developed for these water uses:

- raw drinking water, public water supply and food processing[4]
- aquatic life and wildlife
- agriculture (livestock watering and irrigation)
- recreation and aesthetics[5]
- industrial water supplies

The guidelines are established following a thorough review of the recent scientific literature, guidelines set by other jurisdictions, and environmental conditions in British Columbia. The scientific literature provides information on environmental fate, persistence, and effects of toxicants on various life forms. This information is not always conclusive because it is often based on laboratory testing that, at best, only approximates field conditions. To compensate for this uncertainty, and applying the "precautionary principle", the guidelines have built-in safety factors that are conservative, while taking into account the natural background in the province.

[4] The guidelines apply to an ambient raw water source before it is diverted or treated for domestic use. The Ministry of Health Services regulates the quality of purveyed water.

[5] Guidelines relating to public health at bathing beaches are the same as those developed by the Ministry of Health Services, which regulates the recreation and aesthetic water use.

The guidelines are used to set ambient site-specific water quality objectives for specific waterbodies. In setting the objectives, considerations are given to present and future water uses, waste discharges, hydrology, limnology, oceanography, and ambient water quality conditions at the site in question.

In most cases, the objectives are the same as the guidelines. However, when natural background levels of substances exceed the guidelines, the site-specific objective could be less stringent than the guideline in order to take this high natural level into account. In rare instances—for example, if the resource is unusually valuable or of special provincial or ecological significance—the safety factor could be increased enabling objectives to be more stringent than the guidelines. Another approach would be to develop site-specific objectives by conducting toxicity experiments in the field. However, because this approach is costly and time consuming, it is seldom used.

Neither the guidelines nor the objectives derived from them have any legal standing. However, objectives can be used to calculate waste discharge limits for contaminants. These limits are outlined in waste management permits, orders and approvals, all of which have legal standing. Objectives are not usually incorporated as conditions of a permit.

Water quality guidelines are subject to review and revision, as new information becomes available or as other circumstances dictate.

RECOMMENDED GUIDELINES

THESE GUIDELINES are based on information presented in a consultant's technical report and are summarized in Table 1. Some changes have been made and are identified in the Summary at the beginning of this Overview.

1 RAW DRINKING WATER SUPPLY

The aesthetic objective for temperature of ≤15 °C in water to be used for drinking is adopted from the 'Guidelines for Canadian Drinking Water Quality', which has been accepted by the Ministry of Health Services for application in British Columbia.

2 AQUATIC LIFE

These guidelines are designed to protect aquatic life in fresh, estuarine and coastal marine waters from excessive temperature fluctuations that are influenced by anthropogenic activities during sensitive periods. Given the large variation in water temperatures throughout British Columbia due both to the geographical range of the province as well as the large differences in elevation, ambient temperatures are factored into the guidelines so that they adhere closely to the natural temperature regime to which sensitive organisms have adapted through evolutionary processes. In addition, special recognition in terms of more restrictive guidelines have been recommended for streams and rivers frequented by bull trout (*Salvelinus confluentus*). Dolly Varden (*Salvelinus malma*), once thought to be the same species of char as bull trout, have also been afforded this same special protection because of their close relationship which suggests that both species may be equally sensitive to thermal variations.

To protect freshwater aquatic life, the Canadian Council of Ministers of the Environment (CCME) set a series of complex, narrative guidelines for temperature in 1987. They are appended at the end of this document. The guidelines recommended for British Columbia attempt to remove some of this complexity with more useable, practical guidelines.

2.1 Streams Frequented by Bull Trout (*Salvelinus confluentus*) and/or Dolly Varden (*Salvelinus malma*)

- *the Maximum Daily Temperature should not exceed 15°C.*
- *maximum spawning temperature should not exceed 10°C.*
- *preferred egg incubation temperatures should range from 2-6°C.*

Rationale

Bull trout have demonstrated the highest thermal sensitivity of native British Columbia fish species tested. Hence, more restrictive guidelines specific to streams frequented by this species and their close relative, Dolly Varden, have been recommended to reflect their sensitivity. The use of the Mean Weekly Maximum Temperature (MWMT) is an approach designed to reduce the risk of cumulative stress leading to death, disease, poor reproductive success or poor growth and is consistent with guidelines specified by Oregon, Washington and Idaho. The recommended maximum spawning temperature recognizes the lower thermal tolerance of adults to elevated temperatures during the fall spawning period and provides protection from short-term extreme temperature exposures.

2.2 All Other Streams

Streams with Unknown Fish Distribution

- *the mean weekly maximum temperature (MWMT) = 18°C*
- *the maximum daily temperature = 19°C*
- *maximum daily incubation temperature (Spring & Fall) = 12°C.*

Streams with Known Fish Distribution

- *± 1°C beyond optimum temperature range (as per Table 2, page iii) for each life history phase of the most sensitive salmonid species present.*
- *Hourly rate of change=1°C.*

Rationale

The guidelines for streams and rivers other than those frequented by bull trout and Dolly Varden are based on temperature tolerance data for salmonids. Salmonids are cold-water dependent and prefer a narrow range of water temperatures during critical periods to meet their life history requirements. Temperature tolerance for juvenile salmonids has been determined under laboratory conditions but adults are more sensitive to elevated temperatures. This thermal sensitivity of adults has been taken into consideration by the recommended guidelines. The recommended maximum temperature guideline is expected to support

the maximum productive capacity of stream environments for salmonids in British Columbia. Failure of some egg development has been experimentally determined where incubation temperatures exceed 13°C for sensitive species.

2.3 Lakes

- *±1 °C change from natural condition.*

Rationale

The guideline for lakes are based on natural ambient conditions so that temperatures adhere closely to regimes which organisms have adapted through evolutionary processes.

2.4 Marine and Estuarine

- *±1 °C change from natural condition.*
- *The natural temperature cycle characteristic of the site should not be altered in amplitude or frequency by human activities.*
- *The maximum rate of any human-induced temperature change should not exceed 0.5 °C per hour.*

Rationale

The guidelines for marine and estuarine waters are based on natural ambient conditions so that temperatures adhere closely to regimes which organisms have adapted through evolutionary processes. Insufficient data are available to set specific limits. These guidelines are consistent with those recommended by CCME and other jurisdictions in the Pacific Northwest (e.g., Alaska).

3 WILDLIFE, LIVESTOCK WATERING, IRRIGATION, AND INDUSTRIAL WATER SUPPLIES

An interim guideline to protect wildlife, livestock watering, irrigation and industry from excessive temperature changes in British Columbia waters is based on natural background levels.

- *±1 °C change from natural condition.*

Rationale

The guideline for wildlife, livestock watering, and irrigation are based on natural ambient conditions so that temperatures adhere closely to regimes which plants and animals have adapted through evolutionary processes. The same guideline has been specified for industrial water supplies to ensure that

temperature regimes are close to that which could have been expected under natural situations.

4 RECREATION AND AESTHETICS

The guidelines for temperature in water to be used for recreational activities are adopted from the 'Guidelines for Canadian Recreational Water Quality', which has been accepted by the Ministry of Health Services for application in British Columbia as follows:

- *The thermal characteristics of waters used for bathing and swimming should not cause an appreciable increase or decrease in the deep body temperature of bathers and swimmers.*
- *The upper recommended limit of temperature is 30°C.*

Rationale

Health Canada reports that scientific evidence suggests that prolonged immersion in water warmer than 34 to 35°C is hazardous. The degree of hazard varies with the water temperature, immersion time, and the metabolic rate of the swimmer.

APPLICATION OF GUIDELINES FOR AQUATIC LIFE

The guidelines can be used to assess water quality impacts or as starting points to develop site-specific objectives. It is recommended that the user be familiar with the concepts and guidelines detailed in the supporting technical report *"Towards a Water Quality Guideline for Temperature in the Province of British Columbia"* prepared by Aspen Applied Sciences Ltd. for the former Ministry of Environment, Lands and Parks, prior to making comparisons between monitoring results and guidelines. To assist in designing monitoring programs "Statistical Designs and Sampling Protocols for Monitoring Attainment of Temperature Guidelines," a section of the consultant's report without the cited references is summarized here.

STATISTICAL DESIGNS

The choice of an appropriate test to reliably detect environmental disturbance due to human activities is often difficult if the magnitude of the impact is small relative to natural background parameter variability. As demonstrated for stream environments, the temperature regime varies longitudinally with stream order, width and elevation and can often be modified by land management activities that influence channel width, riparian canopy cover, pool volume, run-off timing and instream flow. Moreover, stream temperature varies daily and seasonally and can be further modified by small-scale (wildfires, floods) and large-scale (global warming) disturbances. Therefore, the challenge exists to select a sampling design that can detect unusual patterns of change in a very interactive and variable measurement.

Paired studies represent the most robust means of comparing the effects of disturbance. The use of paired lakes or paired watersheds is most desirable among any sampling design, but it is often difficult to establish suitable pairs given the ubiquity of land development. As an alternative, sampling designs have evolved to contrast differences in parameters between disturbed and undisturbed sites within the same basin. In its simplest form in stream environments, environmental monitoring to detect change from a given disturbance has been facilitated by comparison of a measurement upstream and downstream from a known point source. An early environmental sampling design employed measurements before and after the initiation of a disturbance at control and impact locations; the

design was originally referred to as *Before-After-Control-Impact* (BACI). This design has been criticized for its failure to account for measurement differences before and after the disturbance and directly related to an impact that could otherwise be explained by natural variation in space and time. The problem is quickly overcome with suitable replication of control and impact locations sampled over time, but may be restrictive due to the number of samples required. The application of this design to rivers, lakes and streams is highly adaptable to the measurement of a variety of disturbances from human activity, but exceedingly more difficult in marine environments where replication of representative habitats or site conditions are required.

The procedure is relatively straightforward where a single putative impact occurs within a basin and becomes progressively more difficult where cumulative effects result from a variety of point and non-point sources, each with its own level of impact. In the simpler cases, application of a BACI design with paired sampling or an asymmetrical design is recommended for statistical comparisons. In the latter instance, additional control locations are incorporated into the design together with a single impact location to account for variability in nature and to detect impacts reliably at either spatial or temporal scales. As with all statistical designs, the rules of representativeness and randomness must apply, and therefore in the case of single point source assessment, control and impact sites should be restricted to the same stream reach and located in similar habitat units. In the more difficult examples where multiple non-point sources occur, it may be more instructive to monitor temperature change at strategic points throughout the basin to determine where temperature maxima may limit the distribution and abundance of biota or impose restrictions on other beneficial uses. In this instance, strategic monitoring locations would likely correspond to areas of increasing stream order from headwaters to confluence. Locations would necessarily correspond to stream reaches above and below land-based developments within the basin. This approach would be highly consistent with ecosystem-level monitoring (i.e., holistic approach) upon which informed management decisions could be based.

SAMPLING PROTOCOLS

The issue of sampling protocols for temperature collection seems relatively clear. In light of today's technologies, there is little question that continuous temperature records should be maintained. Continuous

data loggers not only provide seasonality to temperature collections, but also provide the added advantage of identifying the frequency and duration of temperature extremes. In consideration of their cost relative to the quality and quantity of information provided, continuous records should become the standard with individual measurements collected at hourly intervals. The placement of temperature recorders within the thalweg (the line of maximum depth and velocity in a stream) and at near-shore margins would provide a more reasonable estimate of average temperature within the cross-section at each site. The three stations at each site would also serve as replicates for statistical analysis. The combined procedure would greatly assist calculations of mean weekly maximum temperatures (MWMT) for future enforcement of the recommended guidelines. The incorporation of a temperature recurrence interval during temperature analysis would be beneficial in estimating the probability of exceedence of fixed temperature thresholds throughout the year that coincide with specific life history activities of individual fish species. Calculation of the cumulative probability of a sequence of events within a specified duration is also recommended. Application of this information would suggest periods where fish may be at risk if the cumulative effects of consecutive days of sub-lethal temperatures impart negative biological responses (e.g., increased susceptibility to disease or poor growth). The output of this approach would certainly aid the decision-making process relative to adjudication's on future land-based developments.

APPENDIX

CANADIAN (CCME) ENVIRONMENTAL GUIDELINES FOR TEMPERATURE TO PROTECT AQUATIC LIFE

FRESHWATER

1 THERMAL STRATIFICATION

Thermal additions to receiving waters should be such that thermal stratification and subsequent turnover dates are not altered from those existing prior to the addition of heat from artificial origins.

2 MAXIMUM WEEKLY AVERAGE TEMPERATURES (MWAT)

Thermal additions to receiving waters should be such that the MWAT is not exceeded.

a) In the warmer months, the MWAT is determined by adding to the physiological optimum temperature (usually for growth) a factor calculated as one-third of the difference between the ultimate upper incipient lethal temperature and the optimum temperature for the most appropriate life stage of the sensitive important species that normally is found at that location and time. Some MWAT values are shown in U.S EPA (1976).

b) In the colder months, the MWAT is an elevated temperature that would still ensure that important species would survive if the temperature suddenly dropped to the normal ambient temperature. The limit is the acclimation temperature minus 2°C when the lower lethal threshold temperature equals the ambient water temperature.

c) During reproductive seasons, the MWAT meets specific site requirements for successful migration, egg incubation, fry rearing, and other reproductive functions of important species.

d) At a specific site, the MWAT preserves normal species diversity or prevents undesirable growths of nuisance organisms.

3 SHORT-TERM EXPOSURE TO EXTREME TEMPERATURE

Thermal additions to receiving waters should be such that the maximum temperatures as calculated in a) and b) are not exceeded. Exposures should not be so lengthy or frequent as to adversely affect the important species.

a) For growth, the short-term maximum temperature is the 24-h median tolerance limit, minus 2°C at an acclimation temperature approximating the MWAT for that month.

b) The short-term maximum temperature for the season of reproduction should not exceed the maximum incubation

temperature for successful embryo survival, or the maximum temperature for spawning.

MARINE

Not to exceed ±1°C change from natural background temperature.